Chapter A4: Direct and Indirect Effects of CWIS on Birds

A4-1 Direct Effects on Birds

Chapter Contents

Although most direct effects of cooling water intake structures (CWIS) are on fish and shellfish, there are occasional cases of direct harm to birds. For example, the U.S. Fish and Wildlife Service in Green Bay, Wisconsin has recorded direct mortality of nestling double-crested cormorants (*Phalacrocorax auritus*) at the Point Beach Nuclear Power Plant (Memorandum from Environmental Contaminants Specialist to Special Agent Roy Owens, U.S. Fish and Wildlife Service Green Bay Field Office, February 4, 1993). During one incident in September and October of 1990, 74 cormorants were impinged at the facility. According to the U.S. Fish and Wildlife Service, this number represents 3.2 percent of the total potential productivity of the species. It was concluded that the geographic extent of the impact was much larger than a single colony in Wisconsin because the losses were nestlings that otherwise would have entered the free-flying population. Another incident of avian impingement occurred at the Seabrook Station in 1999. Between February 20 and March 16, twenty-nine white-winged scoters were impinged at the facility's cooling water intake structures. The intake structures are located at a depth of approximately 40 feet below the surface, and mussels often attach to the structures. It is believed that after diving down to feed on the mussels on the intake structures, the scoters were drawn into the cooling system (North Atlantic Energy Service Corporation, 1999).

A4-2 Indirect Effects on Fish-Eating Birds

Although direct mortality of birds can occur, most effects are indirect as a result of losses of fish and shellfish that provide food for birds. For some fish-eating birds, such as cormorants, kingfishers, grebes, ospreys, and terns, fish are a necessary component of the diet. For others, such as gulls, fish are a regular but less essential dietary component. More than 50 bird species out of the 600 in North America fall into the former category, and 20 fall into the latter (Tables A4-1 and A4-2). The birds listed in Tables A4-1 and A4-2 usually obtain their fish prey from freshwater ecosystems such as lakes, ponds, marshes, or rivers (e.g., ospreys and kingfishers), or from estuarine or coastal marine environments (e.g., loons and cormorants). Many species such as grebes and auks spend part of the year (typically the breeding season) in freshwater environments, but winter on the coast. These birds while in their summer or winter ranges may occupy areas that could be affected by existing or future CWIS. Some birds (e.g., shearwaters) depend on fish prey from offshore marine areas. Since these prey are unlikely to be affected by CWIS located inland or on the coast, these birds are not considered in this chapter. Also, most birds are relatively flexible and opportunistic in their choice of prey, and some birds may consume fish, but only rarely; these birds (e.g., red-winged blackbirds) are not included in the tables.

In addition to birds that depend largely on fish for their diet, many species consume aquatic invertebrate prey, such as crustaceans, annelids, mollusks, etc. Bird species that are at least partially dependent on aquatic invertebrates from freshwater wetlands or coastal marine and estuarine habitats for at least part of their annual cycles are shown in Table A4-3. These species may be vulnerable to the secondary effects of CWIS since the planktonic life stages of their prey may be impacted and the local adult communities eventually affected. However, they are probably less vulnerable than the piscivorous birds listed in Tables A4-1 and A4-2 since, unlike fish, it is less likely that most adult invertebrates, which are typically bottom-dwelling, will be directly affected by intake structures.

White winged scoters (*Melanitta fusca*) are one of the 15 species of sea ducks found in North America. They spend most of the year in costal marine waters and migrate inland to nest and raise their young as do most sea ducks. White wings nest on freshwater lakes in the boreal forests of interior Alaska and western Canada and winter in large bays and estuaries along the Pacific and Atlantic coasts.

Source: Alaska Department of Fish and Game, 1999

Photo source: Alaska Department of Fish and Game, 1999

The double-crested cormorant is a bird of salt, brackish and fresh waters. It breeds mainly along the coasts, but also around inland lakes. As soon as they return from their wintering grounds on the U.S. east coast south to the Gulf of Mexico, they appear throughout the St. Lawrence system. They are particularly fond of islands for nesting. The nest is made of a mass of branches which they build in a tree, on a ledge or on a clifftop.

Cormorants are 61-92 cm (2 to 3 ft) long, with thick, generally dark plumage and green eyes. The feet are webbed, and the bill is long with the upper mandible terminally hooked. Expert swimmers, cormorants pursue fish underwater. The young are born blind, and the parents feed the nestlings with half-digested food which is dropped into the nests. Later, the young birds poke their heads into the gullet of the adults to feed. Cormorants are long-lived; a banded one was observed after 18 years.

Average clutch size is three or four eggs. After being incubated by both parents for 24 to 29 days, the chicks hatch unprotected by any down. They grow rapidly and fledge when the are five to six weeks old. Cormorants are diving bird and feed mainly on fish caught close to the bottom. The double crested's diet consists of fish such as Capelin, American Sand Lance, gunnels, Atlantic Herring and sculpins, as well as crustaceans, molluscs and marine worms.

Source: Environment Canada, 2001

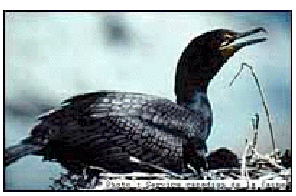


Photo source*:* Environment Canada, 2001

While at their breeding, migration, or wintering sites, the birds listed could be close to one or more existing or planned CWIS, and could be affected by the operation of these facilities. CWIS have the potential to adversely affect these bird populations indirectly by reducing their available food supply (eggs, larvae, juveniles and/or adult fish and invertebrates) through impingement and entrainment (I&E).

Generally, the larger the bird, the larger its prey. Ospreys or bald eagles may take fish that weigh a few pounds. However, many North American fish- and invertebrate-eating birds typically exploit smaller prey species or the younger age groups of larger fish. For example, common terns breeding in Massachusetts feed their young the age groups of species such as sandeels or silversides that are typically less than 6 inches long (Galbraith et al., 1999). CWIS could potentially reduce the availability of the birds' fish or invertebrate prey either directly, by reducing the densities of the larval and older organisms that the birds exploit (through I&E), or indirectly, by reducing the numbers of eggs or larvae to the extent that the density of the older age groups that larger birds rely on is reduced locally. Also, fewer larger fish or adult invertebrates (i.e., the breeding stock) could affect the availability of small prey in the next generation. These cause-effect interactions are displayed in Figure A4-1.

Table A4-1: North American Birds that Eat Fish as a Major Dietary Component	
Major Dietary Component	
Species	**Distribution**[a]
Red-throated loon	summer: lakes in arctic Canada and Alaska; winter: Atlantic and Pacific coasts south to California and Georgia
Pacific loon	summer: lakes in arctic Canada and Alaska; winter: Pacific coast south to California
Arctic loon	summer: lakes in Alaska; winter: Pacific coast south to California
Common loon	summer: lakes in Canada and northern U.S.; winter: Atlantic and Pacific coasts south to Texas and California
Horned grebe	summer: freshwater wetlands in Canada and north-western U.S.; winter: Atlantic and Pacific coasts south to Texas and California
Pied-billed grebe	Resident in freshwater wetlands throughout U.S.
Red-necked grebe	summer: freshwater wetlands in Canada and northern Great Lakes; winter: Atlantic and Pacific coasts south to California and Georgia
Clark's grebe	summer: freshwater wetlands in western U.S.; winter: Pacific coast
Western grebe	summer: freshwater wetlands in Canada and western U.S., winter: Pacific coast
American white pelican	summer: lakes in Canada and western U.S.; winter: California and Gulf of Mexico coasts
Brown pelican	resident: Pacific and Atlantic coasts from Washington and New York south to California and Gulf of Mexico
Anhinga	resident: Atlantic coastal wetlands from South Carolina south to southern Texas
Neotropic cormorant	resident: coastal wetlands in Texas
Great cormorant	summer: maritime east Canada; winter: Atlantic coast south to South Carolina
Double-crested cormorant	summer: lakes in Great Lakes, west U.S. and north-east U.S.; winter: entire Pacific and Atlantic coasts
Brandt's cormorant	resident: Pacific coast from Canada to California
Pelagic cormorant	summer: Alaskan coast; winter: Pacific coast from southern Alaska to California
Least bittern	summer: freshwater wetlands from east coast of U.S. to midwest states; winter: Gulf coast and south Florida
American bittern	summer: freshwater wetlands throughout Canada and U.S.; winter: wetlands on both coasts south to California and Texas
Green heron	summer: freshwater wetlands from Atlantic coast to midwest states and Oregon and Washington; winter: California, gulf of Mexico and Florida coastal wetlands
Tricolored heron	resident: Atlantic coastal wetlands from New York south to Florida and Gulf of Mexico
Little blue heron	summer: freshwater wetlands in Gulf of Mexico States; resident: coasts of Gulf Coast and Florida north to New York
Reddish egret	resident: coastal wetlands in Florida and Gulf Coast
Snowy egret	summer: freshwater wetlands in western States; winter: California coast resident: coastal wetlands from Massachusetts south to Gulf Coast States
Great egret	summer: freshwater wetlands in Mississippi Valley States; resident: Atlantic coastal States from Mid-Atlantic south to Gulf of Mexico; winter: California coast
Great blue heron	summer: freshwater wetlands in northern U.S. States and Canada; winter and resident: wetlands in inland southern states and both coasts of Canada and U.S. south to California and Gulf of Mexico
Wood stork	resident: coastal wetlands in Florida and Gulf of Mexico

Table A4-1: North American Birds that Eat Fish as a Major Dietary Component (cont.)

Major Dietary Component	
Species	**Distribution[a]**
Roseate spoonbill	summer and resident: coastal wetlands in Florida and Gulf of Mexico
Common merganser	summer: lakes in Canada and north-west U.S.; winter: lakes and rivers in interior and coastal U.S. south to California and North Carolina
Red-breasted merganser	summer: lakes in Canada; winter: Atlantic and Pacific coasts from Canada south to California and Gulf of Mexico
Hooded merganser	summer: lakes and rivers in Canada and Great Lakes States; winter: Pacific coast from Canada south to California and from New York south to Gulf of Mexico. Also winters in interior states of south-east U.S.
Osprey	summer: inland and coastal wetlands from Canada south to Great Lakes, Pacific Northwest, and Florida and Gulf of Mexico; resident: Florida and Gulf Coast states
Bald eagle	summer: lakes and rivers in Canada, Great Lakes, north-eastern U.S., Pacific Northwest, and some western states; winter: Midwestern and western states and both coasts south to Mexican border
Sandwich tern	Atlantic coastal areas from Mid-Atlantic states south to Gulf of Mexico
Elegant tern	summer: Southern California coast
Royal tern	Summer and resident Atlantic coasts from Mid-Atlantic states south to Gulf of Mexico; winter: southern California coast
Caspian tern	summer: Canadian wetlands, Great Lakes, and some western states; winter: Florida and Gulf of Mexico coasts, southern California coast
Roseate tern	summer: coasts of Newfoundland south to New York
Forster's tern	summer: inland wetlands in central Canada and western States of U.S. Also summers on coastal marshes in Gulf of Mexico; winter: southern California and south Atlantic coasts south to Florida and Gulf of Mexico
Common tern	summer: inland lakes of Canada and northern U.S. states and coastal Atlantic from Newfoundland south to North Carolina
Arctic tern	summer: tundra in Arctic Canada and arctic coasts south to Newfoundland and Maine
Least tern	summer: Atlantic and California coastal dunes south to Florida and Gulf of Mexico. Also rivers in Mississippi Valley
Black skimmer	summer: inland and coastal wetlands in southern California; resident and winter: Atlantic coast from New York south to Florida and Gulf of Mexico
Common murre	winter: Atlantic and Pacific coasts south to New York and California
Razorbill	winter: Atlantic coast south to Mid-Atlantic states
Black guillemot	resident: Atlantic coast from arctic south to New England
Pigeon guillemot	resident: Pacific coast from Arctic south to California
Marbled murrelet	resident and winter: Pacific coast south to California
Rhinoceros auklet	resident and winter: Pacific coast south to California
Atlantic puffin	resident and winter: Atlantic coasts from Newfoundland south to New England
Horned puffin	resident and winter: Pacific coasts fro Alaska south to Washington
Tufted puffin	resident and winter: Pacific coasts from Alaska south to California
Belted kingfisher	summer: lakes and rivers throughout Canada; resident and winter : lakes and rivers throughout U.S.

Note: Excluded are species that are rare or have highly restricted distributions, that feed mainly offshore, or that eat fish only very rarely.
[a] These distributions are approximate. For more detailed representations see, for example, Kaufman, 1996.
Source: Kaufman, 1996.

Table A4-2: North American Birds that eat Fish as a Frequent Dietary Component

Frequent Dietary Component	
Species	**Distribution[a]**
Clapper rail	resident: Atlantic coastal marshes fro New England south. Also San Francisco Bay
King rail	summer: inland marshes from Atlantic coast to midwest; resident and winter: Coastal marshes from Mid-Atlantic States south to Florida and Gulf of Mexico
Whooping crane	winter: Texas coast
Heerman's gull	all year: Oregon and California coasts
Laughing gull	resident: Atlantic coasts from New England south to Gulf of Mexico
Franklin's gull	summer: prairie wetlands in central Canada and northern U.S.
Bonaparte's gull	summer: forested wetlands across Canada; winter: Atlantic and Pacific coasts from Canada south to California and Gulf of Mexico
Ring-billed gull	summer: lakes in central Canada, Great Lakes and Maritime Provinces; winter Atlantic coast from New England south to Mexico, Pacific coast from Canada south to Baja, and interior southern states of U.S.
Mew gull	summer: freshwater wetlands in western Canada; winter: Pacific coast from Canada south to California
California gull	summer: lakes in central Canada and western U.S.; winter: Pacific coast from Washington south to California
Herring gull	summer: inland and coastal lakes across Canada; winter: Pacific and Atlantic coasts from Canada south to Mexican border
Glaucous gull	summer: arctic; winter: Atlantic and Pacific coasts south to Mid-Atlantic States and California
Iceland gull	summer: arctic; winter Atlantic coast from Canada south to New York
Thayer's gull	summer: arctic; winter: Pacific coast from Alaska south to California
Western gull	resident: Pacific coast from Canada south to Baja
Glaucous-winged gull	resident: Pacific coast of Canada; winter: Pacific coast of U.S.
Great black-backed gull	resident and summer: Maritime provinces south to Mid-Atlantic States
Black tern	summer prairie and forested wetlands across Canada and in Midwestern and western states of U.S.
Ancient murrelet	summer: Alaska winter: Pacific coast from Alaska south to California
American dipper	resident: rivers throughout western States of U.S.

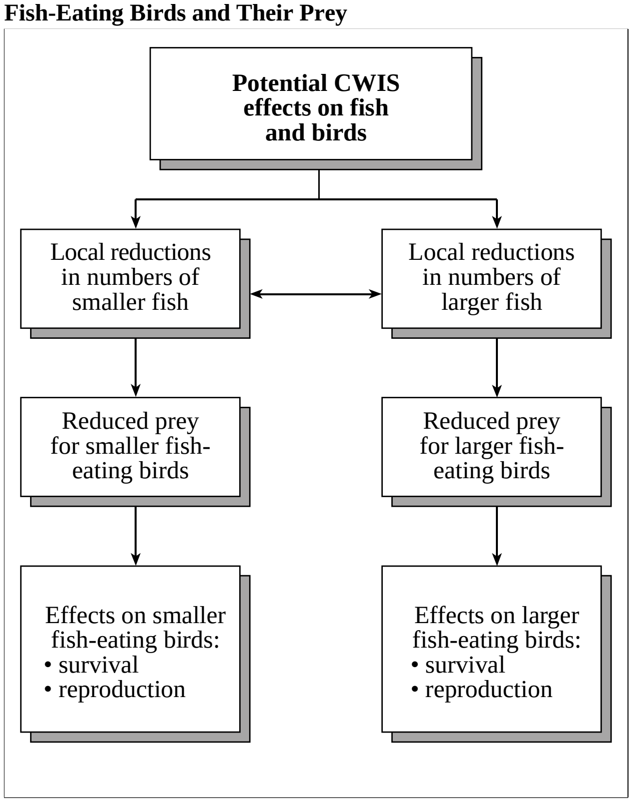
Table A4-3: North American Birds that Eat Mainly Aquatic Invertebrates			
Species	**Distribution[a]**	**Species**	**Distribution[a]**
Eared grebe	summer: freshwater wetlands in western Canada and U.S.; winter: Pacific coast from Vancouver south to southern California	Piping plover	summer: coast, lake and river beaches in northern Midwest and New England; winter: Atlantic coastal beaches from New England south to Mexico
Black-crowned night-heron	summer: inland and coastal wetlands in southern Canada and across whole of U.S.; winter and resident: coast of Florida and Gulf of Mexico	American oystercatcher	resident: Atlantic coastal beaches from New England south to Texas
Yellow-crowned night-heron	resident and summer visitor to interior and coastal wetlands in south-eastern States of U.S.	Black oystercatcher	resident: Pacific coastal beaches from Canada south to California
White ibis	resident: south east Atlantic coast from South Carolina to Texas	Black-necked stilt	summer: alkaline marshes in western States; winter: California, Florida and Gulf of Mexico coasts
Glossy ibis	resident and winter: coastal marshes on Atlantic coast from New England south to Texas	Greater yellowlegs	summer: northern Canada; winter: Atlantic coast from New York south to Mexico
White-faced ibis	summer: lakes in some western States of U.S.; winter: Gulf of Mexico and coastal and interior California	Lesser yellowlegs	summer: northern Canada; winter: Atlantic coast from New York south to Mexico
Roseate spoonbill	resident: Florida and Gulf Coast coastal wetlands	Willet	summer: wetlands in some western States and saltmarshes on Atlantic coast from New England south to Mexico; winter: Atlantic coast from New England south to Mexico and California coast
Greater scaup	winter: throughout Atlantic and Pacific coasts of U.S.	Spotted sandpiper	summer: inland wetlands throughout Canada and mid and northern U.S. States winter: Florida and Gulf of Mexico coasts
Lesser scaup	summer: prairie wetlands in western states; winter: wetlands in southern states and Pacific and Atlantic coasts from Canada south to Mexico	Long-billed curlew	winter: Texas and California coasts
Common eider	winter: New England coast	Marbled godwit	summer: wetlands in northern prairies winter: Atlantic and Pacific coasts from Delaware to Texas and California
King eider	winter: New England coast	Ruddy turnstone	winter: Atlantic coast south of New England
Harlequin duck	summer: rivers in western Canada and Pacific Northwest winter: Atlantic and Pacific coasts as far south as California and New England	Surfbird	winter: Pacific coast from Canada to California
Oldsquaw	summer: arctic winter: Pacific and Atlantic coasts south to California and Texas	Red knot	winter: Florida coast
Black scoter	winter: Pacific and Atlantic coasts south to California and Texas	Sanderling	winter: Atlantic and Pacific coasts from New York south to Texas and Vancouver to Baja
Surf scoter	summer: northern Canada; winter: Pacific and Atlantic coasts south to California and Texas	Western sandpiper	winter: Atlantic and Pacific coasts from New York south to Texas and Vancouver to Baja
White-winged scoter	summer: northern Canada; winter: Pacific and Atlantic coasts south to California and Texas	Least sandpiper	winter: Atlantic and Pacific coasts from New York south to Texas and Vancouver to Baja
Common goldeneye	winter: freshwater and coastal wetlands throughout U.S.	Purple sandpiper	winter: Atlantic coast from Canada south to Mid-Atlantic States

Table A4-3: North American Birds that Eat Mainly Aquatic Invertebrates (cont.)

Species	Distribution[a]	Species	Distribution[a]
Barrow's goldeneye	summer: rivers in northern Rocky Mountain States; winter: Rocky Mountain States	Rock sandpiper	winter: Pacific coast from Canada south to California
Bufflehead	summer: Canadian wetlands; winter: freshwater and coastal wetlands throughout U.S.	Dunlin	winter: Atlantic coast from New York to Texas and San Francisco Bay
Limpkin	resident: Florida wetlands	Dowitcher species	winter: Atlantic and Pacific coasts from Northern U.S. south to Baja and Mexico
Black-bellied plover	winter: Pacific and Atlantic coasts south to Mexico		
Snowy plover	summer: alkali lakes in western U.S.; resident: coastal wetlands in California and Gulf Coast		
Wilson's plover	resident: Atlantic coast wetlands from New York south to Gulf Coast		
	summer: arctic; Winter Pacific and Atlantic coast wetlands from Canada south to California and Mexico		

[a] These distributions are approximate. For more detailed representations see, for example, Kaufman, 1996.

Figure A4-1: Potential CWIS Effects on Fish-Eating Birds and Their Prey



A4-3 Understanding the Effects of Food Reduction on Bird Populations

Many scientific studies have confirmed the link between the abundance of available food and the viability of bird populations. EPA reviewed recent papers published in the peer-reviewed literature that describe effects of food shortages on fish-eating birds. One of the goals of these studies was to identify linkages between food shortages and adverse impacts on birds, irrespective of the underlying cause of the shortage[1]. While EPA's review of these studies did not reveal any documented linkages between I&E and effects on bird populations, the principle remains the same: independent of the stressor, a reduction in the food supply can adversely affect bird populations. Table A4-4 summarizes a sample of the reviewed studies, and Boxes A4-1 and A4-2 describe the findings of two studies in greater detail. Several broad conclusions can be drawn from this body of literature:

- Chicks of fish-eating birds can starve and quickly die (in a few days) if food is scarce or unavailable during a short window of natal development.
- The amount of food that is available before and during the birds' breeding seasons can affect courtship and initiation of breeding, number of eggs laid, chick survival, frequency of renesting, and other important reproductive factors.
- Insufficient amounts of food may force parents to forage farther and wider, resulting in fewer and smaller feeds per chick per day. This may increase the risk of starvation.
- Food shortages can result in increased food theft, as chicks and adults steal food from each other.
- Food shortages during the breeding season usually affect chicks and fledglings before the adults.
- Inadequate nutrition during development can have significant physiological consequences (e.g., calcium deficiencies and poor skeletal development).
- Super-abundant food can lead to increased breeding success.

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[1] Causes of food shortages included spawning failure in fish, shifting weather patterns, effects of pollutants, and other factors.

Table A4-4: Examples of Studies Showing Relationships between Quantity and Quality of Fish Prey and Survival, Behavior, and Reproductive Success of Fish-Eating Birds

Country	Waterbody	Target Species	Study Description	Summary	Reference
USA	Laboratory	Belted kingfisher	Effect of food supply on reproduction	Extra food resulted in earlier nesting, heavier chicks, and greater frequency of second clutches	Kelly and Van Horne, 1997
USA	Reservoir	Double-crested cormorant	Identification of factors associated with densities of cormorants	Fish availability correlated with cormorant density	Simmonds et al., 1997
Spain	Ebro Delta	Audouin's gull	Availability of trawler discards and kleptoparasitism	Reduced discards led to increased rates of kleptoparasitism	Oro, 1996
The Netherlands	Inland waters	Black tern	Impacts of acidification on fish stocks and chick growth and survival	Reduced fish stocks led to calcium deficiencies and increased mortality	Beintema, 1997
Northern Ireland	Lough Neagh	Great cormorant	Identification of factors associated with densities of cormorants	Fish availability correlated with cormorant density	Warke et al., 1994
France	Rhone Delta	Little egret	Food abundance and reproductive success	Increased food led to increased reproductive success and fledgling survival	Hafner et al., 1993
Norway/Russia	Barents Sea	Kittiwakes, murres, puffins	Fish availability and reproduction of birds	Reductions in fish stocks impaired breeding success	Barrett and Krasnov, 1996
USA	Pacific Ocean	Kittiwakes, gulls, and puffins	Diets and breeding success	Diet switching led to reduced breeding success	Baird, 1990
Germany	North Sea	Common tern	Food supply and kleptoparasitism	Reduced food supply caused increased kleptoparasitism	Ludwigs, 1998
Germany	North Sea	Common tern	Food supply and chick survival	Reduced food caused increased chick mortality	Becker et al., 1997
South Africa	Indian Ocean	African penguin, Cape gannet, Cape cormorant, swift tern	Prey availability and breeding success	Reductions in anchovy stocks resulted in reduced breeding success	Crawford and Dyer, 1995
UK	Atlantic Ocean	Arctic tern	Fish abundance and breeding success	Reduced fish stocks lowered egg volume, clutch size, and breeding success	Suddaby and Ratcliffe, 1997

Box A4-1: Fish Availability Affects Breeding Success in Arctic Terns.

The arctic tern is a small, circumpolar, fish-eating bird that typically obtains its prey in the inshore marine environment. Unlike the closely related common tern, arctic terns do not generally breed or feed in freshwaters.

In the United Kingdom, the Shetland Islands are one of the strongholds of the species. Large breeding colonies of thousands of pairs of birds can be found there. Such large breeding colonies require an abundant and predictable food supply. In the Shetlands the most important food species is the sandeel, which occurs in vast shoals in the inshore waters. Before the 1980's, sandeels were largely ignored by the UK fishing industry. However, beginning in the late 1970's, they became an increasingly sought after catch as their value as fodder for farm animals was recognized. This led to a huge sandeel fishing industry that, since it was largely unregulated, resulted in the 1980s in massive depletion of the fish stocks. This study by Monaghan et al. (1989) investigated the effects of this stock depletion on the breeding biology of arctic terns in the Shetlands (where the sandeels were overfished) and at Coquet Island in England (where food supplies were not reduced).

Of the interesting differences found in the breeding biology of the terns from the two colonies, many could be ascribed to the reduction in prey availability at the Shetland colony. The Shetland birds delivered smaller sandeels to their nests than did the Coquet birds, indicating that the fishing industry had removed the larger (and more nutrient- and energy-rich) fish. Also, because of this, the chicks in the Shetland colony grew at a slower rate than the Coquet chicks and the majority of the chicks in the colony died a few days after hatching. The Coquet chicks had more rapid growth rates and far better survival.

The adult birds were also affected by the reduced sandeel stocks. During the breeding season, the adults in the Shetland colony lost weight and became lighter than the adults at Coquet, suggesting a food shortage effect.

This study clearly demonstrates the importance of having an adequate and predictable fish food supply for arctic terns during the breeding season and on their ability to raise chicks.

Box A4-2: Oceanic Currents, Human Fisheries, Anchovy Abundance, and the Abundance of Peruvian and Chilean Seabird Populations.

Several fish-eating seabirds breed in extremely large colonies on islands off the coasts of Peru and Chile. The breeding populations of these cormorants and boobies probably number several million in a typical year. These huge populations are made possible by an extremely rich supply of anchovies, which, in turn, depend on upwelling associated with the Humboldt current bringing nutrient-rich cold water to the surface close to the nesting islands (Harrison, 1983). In typical years, these birds can easily raise their young by exploiting the rich fish prey base.

However, every 10 or so years an El Niño event forces the upwelling south and deprives the seabirds of their anchovy prey. In these years, the birds may have reduced reproductive success or may fail to breed at all. Further, the birds may desert their normal ranges and spread north and south along the Pacific coast into areas where they are not normally seen (Murphy, 1952).

In the last few decades a new factor has complicated this pattern. The human anchovy fishery has now reduced the numbers of fish to the extent that even in good years the numbers of breeding birds and their success may be reduced.

The sensitivity of these seabirds to temporal and spatial disturbances in the dependability of their food supply highlights the critical relationship between the availability of fish prey and their population status.

This information shows that the responses of fish-eating birds to food shortages can range from behavioral changes (e.g., greater foraging efforts or increased food theft) to more dramatic responses (e.g., clutch abandonment, chick mortality, failure to attempt to breed). It is not likely that I&E by CWIS has resulted in such large-scale die-offs and reproductive failures. Such obvious responses would have been observed and reported. CWIS I&E effects are, therefore, likely to be more subtle. However, even these types of responses could have longer-term population impacts.

The studies reported in Table A4-1 show that chicks in particular are prone to rapid starvation and increased mortality during early development. During that period, sufficient amounts of high quality food (i.e., nutritionally and energetically rich) must be available to ensure successful fledging. The potential effects of I&E could be magnified if the depletion of a localized high quality fish resource forces parents to switch to a lower quality food or to forage further afield, resulting in a decrease in the rate of food delivery to the chicks and an increased starvation risk. Alternatively, I&E effects on local food supplies could affect bird populations when they are under stress from some other factor (e.g., severe weather or contaminants). Thus, the potential effects of I&E on bird populations, though perhaps subtle, cannot be discounted.

Even when enough food is available to allow a “normal” reproductive event, any additional food can increase the survival rate of nestlings and increase overall breeding success (Hafner et al., 1993; Suddaby and Ratcliffe, 1997). This at least partly rebuts the commonly used argument that surplus fish production has no ecological value and can therefore be removed without affecting the local ecosystem. It also suggests that even though the I&E of large numbers of fish might not actually adversely affect birds, the removal of that extra food resource could just as easily prevent them from realizing their full reproductive potential.

Even if a bird species can switch to another food source, significant effects are still possible if the replacement food has lower caloric or nutritional quality (Beintema, 1997). Recently hatched chicks can be particularly vulnerable to changes in food availability, starving and dying in a short time. Such risks may be of particular concern if the CWIS removes large numbers of fish or other aquatic prey in bird foraging areas during the breeding season.

In conclusion, this review of the ornithological literature underscores the link between adequate food supplies and survival and reproductive success in fish-eating birds. In particular, the low degree of behavioral flexibility combined with severe food shortages can result in reduced survival or increased reproductive failure. As the data shown in Table A4-3 suggest, localized food shortages caused by I&E are likely to affect bird populations differently depending on their dietary requirements. Species that can readily switch to an alternative prey may be less vulnerable, and those others that are entirely dependent on fish stocks may be more vulnerable. This leads to two conclusions: 1) any impacts associated with the removal of prey fish by I&E are likely to be species-specific, and 2) birds entirely dependent on fish (e.g., ospreys or loons) have a greater risk of being adversely affected compared to species with more flexible dietary requirements.